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Carbon Capture and Sequestration R&D Supported by DOE Office of Science

Jerry W. Elwood
Director, Climate Change Research Division
Office of Biological and Environmental Research

Third Annual Conference on Carbon Capture and Sequestration
Hilton Alexandria Mark Center
Alexandria, Virginia
May 6, 2004

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Office of Science R&D on Carbon Sequestration

Fundamental science on geologic, ocean, and terrestrial sequestration, and advanced biological concepts for sequestration

- **Basic research on sequestration -- supports the U.S. Climate Change Technology Program (CCTP)**
- **Support of experimental investigations, process studies, and numerical modeling that can provide information and data to enable:**
  - **Improvement of existing sequestration concepts and approaches;**
  - **Development of advanced, new sequestration concepts and strategies;**
  - **Assessment of potential efficacy of existing strategies under consideration;**
  - **Assessments of potential environmental consequences of sequestration concepts.**

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Office of Science R&D on Carbon Sequestration

Geologic sequestration research– Office of Basic Energy Sciences

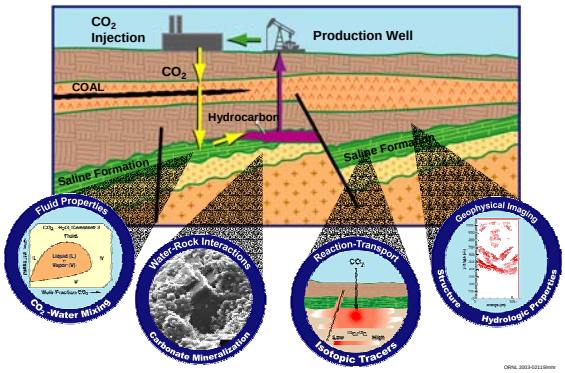
Research critical for understanding how to make geological sequestration effective and safe.

Research that will help provide a sound scientific basis for both assessing long-term storage security and risks and defining performance requirements.

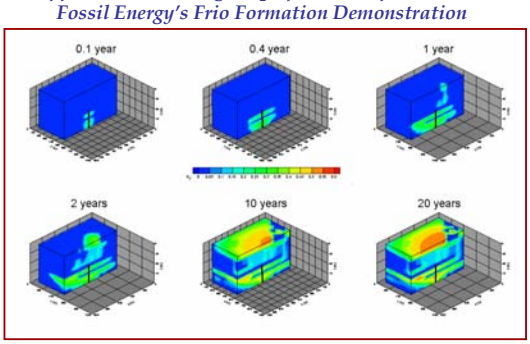
- **Geochemical investigations of rock-water interactions; how CO_2 disposal would change the geological and hydrological stability of subsurface formations**
- **Hydrological, mechanical, and chemical numerical modeling of the physics of subsurface fluid flows, e.g., flow of injected CO_2**
- **High resolution geophysical imaging to understand and track potential impacts of injected CO_2**

Office of Science - OBES Geosciences Program

Fundamental Research into Subsurface Processes



Computational Modeling Capability Developed by SC Applied to Predicting CO_2 Injection Performance in Fossil Energy's Frio Formation Demonstration



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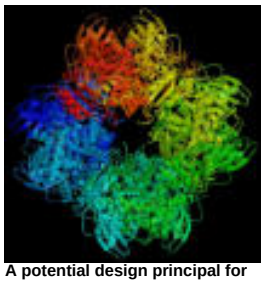
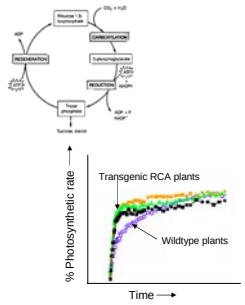
Energy Biosciences Sequestration Research – Office of Basic Energy Sciences

- Research to understand biological regulatory mechanisms for more efficient synthesis and utilization of carbon-containing materials by plants and microbes
- Understanding biochemical and metabolic pathways of assembly of stable macromolecules by plants and microbes
- Carbon fixation and its subsequent assimilation, storage, and mobilization for growth by plants and microbes

Improving Carbon Fixation by Altering Regulation of Rubisco, the enzyme in plants that fixes atmospheric CO_2 during photosynthesis



A potential design principal for enhancing the ability of plants to remove CO_2 from the atmosphere



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Terrestrial Sequestration – Office of Biological and Environmental Research

Research to develop approaches for enhancing carbon sequestration in terrestrial ecosystems – long-lived vegetation and soil pools

- **Field and lab studies to identify processes controlling carbon sequestration in terrestrial ecosystems**
- **Geochemical and biological process studies on how to modify natural processes to enhance carbon sequestration in long-lived vegetation and soils**
- **Develop new, reliable methods for measuring and monitoring carbon sequestration in terrestrial systems**

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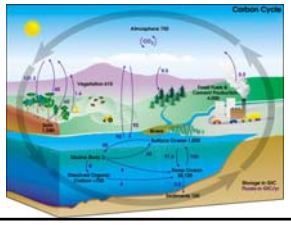
AmeriFlux – Processes Controlling Sources and Sinks

- **~ 80% of CO_2 taken up by photosynthesis at >30 flux sites is returned to the atmosphere by respiration**
- **Implies net uptake and sequestration of carbon averages 20% of gross photosynthesis in some mature forests (Law et al. Agric. For. Meteorol. 2002)**



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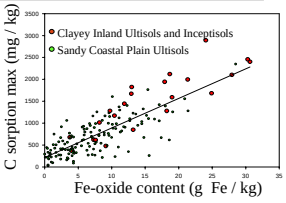
Terrestrial Carbon Sequestration -- Soil Manipulation:
Mobilization to deeper horizons

- **Enhance iron oxide content**
- **More carbon input to deep soil profile**
- **Quantify root-microbiology processes**

Rhizotron Observation of Root-Soil Interaction



Mobilized Carbon in Tropical Soil Profile

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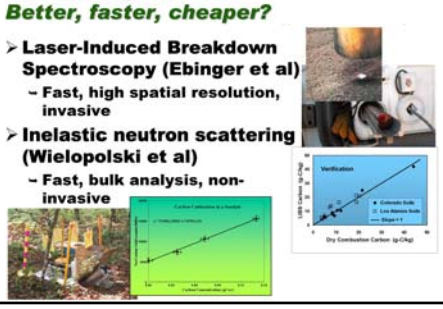
Office of Science R&D on Carbon Sequestration

Measuring Soil Carbon
Better, faster, cheaper?

- **Laser-Induced Breakdown Spectroscopy (Ebinger et al)**
  - **Fast, high spatial resolution, invasive**
- **Inelastic neutron scattering (Wielopolski et al)**
  - **Fast, bulk analysis, non-invasive**



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Ocean Sequestration – Office of Biological and Environmental Research

Fundamental research on efficacy and consequences of enhancing the "biological pump" and of deep ocean disposal of CO_2

- **Experimental studies on iron fertilization to assess the efficacy of enhancing ocean "biological pump" – eliminate constraint of nutrient supply on carbon fixation**
- **Experimental studies of impacts on ocean chemistry and biology of injecting a pure stream of CO_2 into deep ocean – CO_2 not an inert gas**
- **Numerical modeling to project long-term fate of CO_2 injected into deep ocean and of carbon sequestered by enhanced biological pump**

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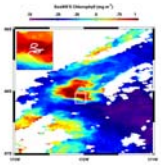
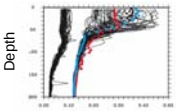
Ocean Carbon Sequestration

Southern Ocean Iron Enrichment Experiments (SOFeX)



Iron added to ocean surface (50 ppt, 100 times background) triggered massive phytoplankton bloom



POC surrogate

Phytoplankton from outside (left) and inside (right) an enriched patch

Vertical profiles of particulate organic carbon (POC) outside (left) and inside (right) an enriched patch

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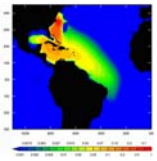
Ocean Carbon Sequestration

Direct Injection



- Laboratory and deep sea experiments on effects of direct injection of liquid carbon dioxide – effects on chemistry and marine biology
- Simulated fate of CO_2 injected into the deep ocean and how long it would remain isolated from the atmosphere – effectiveness for long term carbon sequestration

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Advanced biological concepts for carbon sequestration

- Functional genomics and proteomics of microbes that will enable development of new and more effective strategies for carbon capture and sequestration
- Functional genomics and proteomics of poplar and other plant species that are relevant to carbon sequestration
- Functional genomics of microbes in poplar rhizosphere that affect transfer of carbon between roots and soil
- Advance concepts – search for genes and gene functions in microbes with potential applications in carbon sequestration

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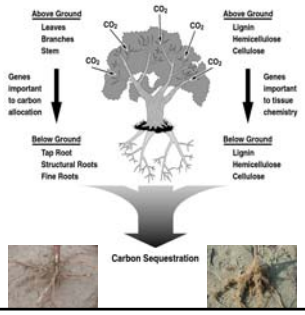
The Populus Tree for Carbon Sequestration

A *Populus* tree

Greenhouse testing

Genome-Enabled Discovery of Carbon Sequestration Genes in *Populus*



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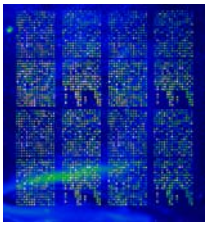
Terrestrial Carbon Sequestration

Functional Gene Arrays allow insights into microbial processes, community structure, and role in carbon sequestration

6,698 gene probes from 30 organisms
- **Nitrogen cycling: 1,882**
- **Sulfate reduction: 1,050**
- **Carbon cycling: 1,810**
- **Phosphorus utilization: 156**
- **Organic degradation: 1607**
- **Metal resistance and oxidation: 193**

Sample from reclaimed mined lands (Collaboration with NETL Project)



Microbial Microarray

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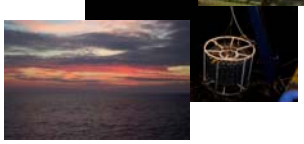
Microbial Solutions from the Sargasso Sea?



Understanding the genetic and biochemical diversity in our oceans may lead to new methods for carbon sequestration or alternative energy production.

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Funding for Carbon Sequestration Research in Office of Science

Program Office & Area	FY 2004	FY 2005 Requested
	($ in millions)	
BES Geologic Sequestration	$ 2.6	$ 2.7
BES Energy Biosciences Sequestration	$ 4.0	$ 4.0
BER Terrestrial Sequestration	$ 4.7	$ 4.7
BER Ocean Sequestration	$ 3.9	$ 3.8
BER Advanced Sequestration Concepts	$19.8	$20.6
TOTAL	**$35.0**	**$35.9**